sealed lead-acid (SLA) battery charger

for 6 V and 12 V (VR)SLA batteries

Yuasa, Kobe, Sonnenschein and Varta are but a few of countless manufacturers of sealed lead-acid (SLA) batteries. Although these batteries have been around for many years, their use in amateur and hobbyists circles has seen an upsurge recently because of price cuts in the surplus trade, at car boot sales and flea markets. The compact, easy to handle 6-volt and 12-volt types with capacity ratings up to 30 Ah can be picked up cheaply and appear to be the most popular. SLA batteries require a simple but fairly unusual charge algorithm for which a low-cost circuit is described in this article.

Design by K. Walraven

Piles of SLA and VRSLA (valve regulated sealed lead-acid) batteries are a common find on almost any electronics-related car boot sale or rally these days. In some cases, the batteries are claimed to be new, and indeed we have the seen the odd SLA with the manufacturer's seal still clamped on to the terminals. Most SLA batteries found in the surplus trade are, however, the result of 'contractual maintenance work' on commercial equipment, usually surveillance or computer-related.

Whatever the source of the SLA battery, whether it is 'used', 'new', 'ex-equipment' 'reconditioned' or 'fully tested & guaranteed', what you take home for a fiver or so will rarely achieve the capacity specified by the

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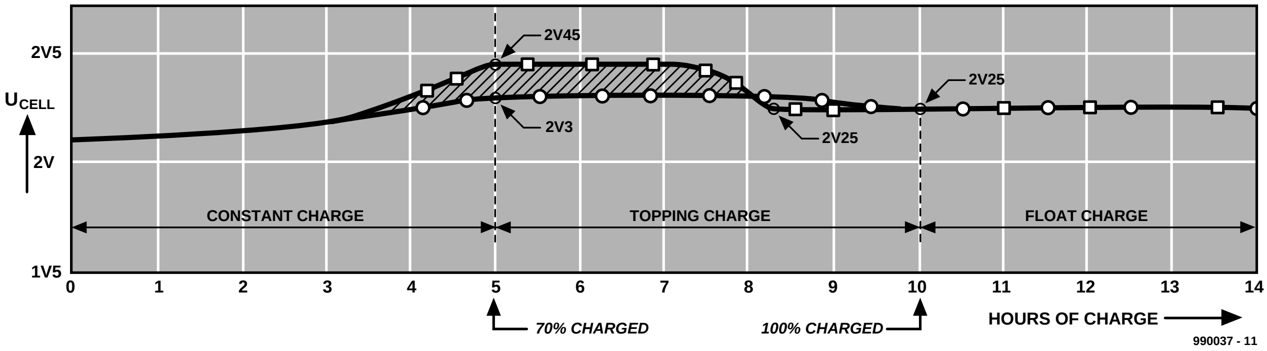
Figure 1. Manufacturers of (VR)SLA batteries specify this charging algorithm. The choice between the lower and higher cell voltage (lines marked with ❍ and ❑ respectively) to begin the topping-charge phase will mostly depend on the time available for charging. Note that the duration of the topping-charge phase applies to low-level charging only (max. cell voltage 2.30 V).



manufacturer. This is because the battery will typically have been in storage for a long time with no standby charge applied.

Although buying an SLA battery on a flea market is always something of a gamble, do remember that if your bargaining was right you should not have paid more than one tenth of the original cost and the battery you are taking home may have enough capacity left for years of trouble-free use in or around the shack. If you do not like gambling and want to have the full battery capacity as printed on the device (the Ah figure), then leave flea markets for what they are and prepare for the shock you will get when enquiring about a the one-off price of a new, guaranteed SLA battery.

SLA BATTERIES — GENERAL

The plastic-contained SLA battery is actually no more than a technical refinement of the *flooded* lead-acid battery originally invented by Gaston Planté in 1859. The *sealed* or *valve-regulated sealed* version, sometimes also sold under the trademark 'Gelcell', is typically used in portable equipment. Compared with the common-or-garden flooded lead-acid battery (as used in your car, for example), the SLA is marked by a lower over-voltage potential which has to be strictly observed during charge to stay well below the gas-generating level which causes water depletion. Most SLAs will vent at about 5 psi, a condition which is to be avoided at all times because highly corrosive and flammable gases are released.

A typical capacity range for SLA batteries obtainable in the surplus trade is 4 Ah to 30 Ah and their original applications include UPS (uninterruptible power supply) systems, wheelchairs, security lighting systems, biomedical instruments and transportable radio and satellite uplinking terminals. The designer of the charger described in this article employs a 6-volt 4-Ah SLA battery to power a helmet light for his cave exploration hobby.

The advantages of SLA batteries are low self-discharge, the total absence of the dreaded 'memory effect', minimal maintenance requirements, very high charge retention and, of course, low cost. On the down side, the SLA battery is heavy and does not lend itself to very fast charging. It also has the lowest energy density of all rechargeable batteries and, importantly, it must be stored in a charged state. Failure to comply with the latter requirement may cause *sulfation*, a condition which, depending on its progress, gradually prevents the SLA from accepting charging current! Finally, because of its lead content, an SLA battery has to be disposed of according to the regulations provided for Chemical Waste Disposal by your local Council.

CHARGE ALGORITHM

The charge algorithm for SLA batteries is basically 'voltage-limit' (rather than 'current-limit' as used for NiCd and NiMH batteries). Normally, a slow 14 to 16 hours are required to fully charge an SLA battery.

The algorithm illustrated in **Figure 1** is the 'official guide' and based on the use of a so-called *multistage charger*. The algorithm comprises three phases: (1) *current charge*; (2) *topping charge* and (3) *float charge*. Note that the voltage

Sulfation
(or, storage — free of charge)

Even the shiniest SLA battery you may bring home from a car boot sale, rally etc., may fail to achieve the rated capacity (in Ah) boldly specified by the manufacturer on the plastic case. The reduced performance is caused by a metabolism inside the battery, called ***sulfation****. Sulfation occurs to a small extent in any lead-acid battery, but in the case of SLA batteries the process is helped by the long-time absence of the float-charge (or 'maintenance') voltage, or the occasional topping-charge, while the battery is in storage.*

A simple but by no means foolproof method of estimating the chances of (partial) recovery from sulfation is to measure the battery terminal voltage under light load conditions. A cell voltage equal to or greater than 2.10 V (i.e., 12.6 V or 6.3 V) indicates a good chance of regaining at least some of the lost capacity.

Suggested methods to restore the battery include applying a charge on top of a charge (observing a 24-48 hour rest period) and applying an over-charge voltage of 2.5 Volts per cell for one or two hours. The latter method requires (1) extreme caution, (2) extensive battery temperature checking and (3) equally extensive safety precautions against the risk of the cell pressure exceeding the venting level (usually at 5 psi). Don't try this at home!

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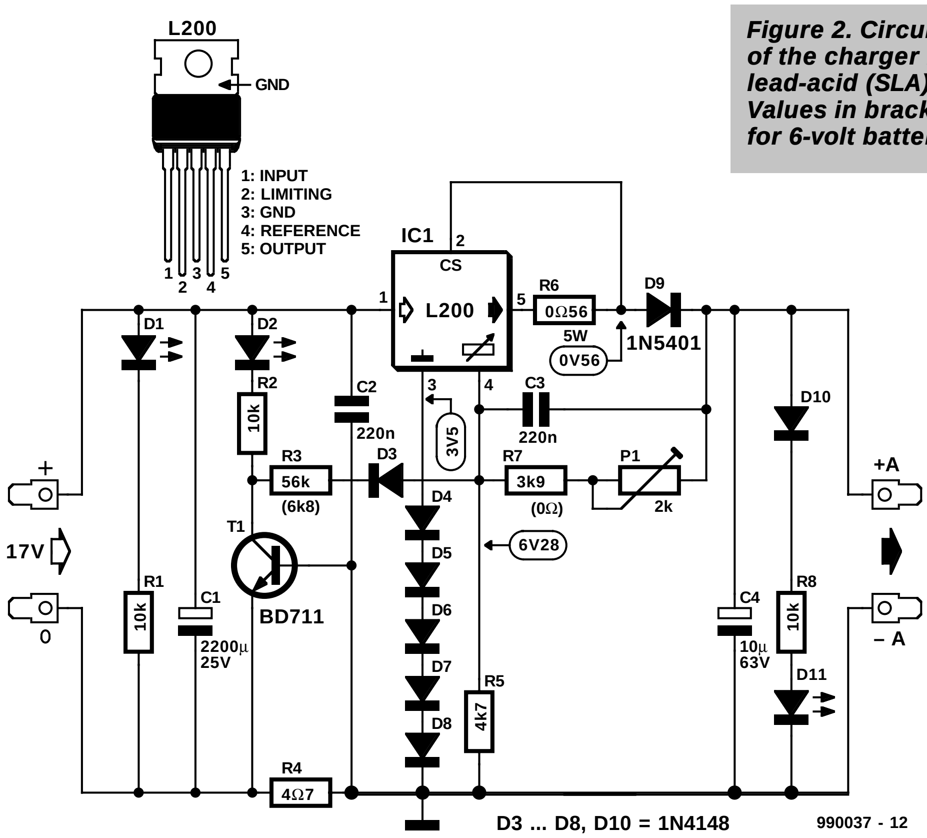

Figure 2. Circuit diagram of the charger for sealed lead-acid (SLA) batteries. Values in brackets are for 6-volt batteries.

shown on the vertical axis is the cell voltage, *not* the battery voltage. A 6-volt SLA battery has three cells, a 12-V battery, six.

During the first five hours or so, the battery is charged with a current of up to 0.5 *C* ampères (typically 0.2 or 0.3 *C*) to about 70% of its nominal capacity. The remaining 30% are accumulated during the topping-charge phase, which should typically last another five hours. It commences when the cell voltage reaches a value between 2.30 V and 2.45 V. These two levels represent the lower and upper extreme respectively, and their use is governed by advantages and disadvantages as shown in **Table 1**. According to the book, the float-charge voltage should be 2.25 V. For a 12-V battery that works out at about 13.5 V.

As shown in Figure 1, the charge time may be reduced by a few hours by using the higher charging voltage of 2.45 V. The float-charge voltage (phase 3) remains the same, however, at 2.25 V (typically) and may be applied for years on end if necessary, which makes the SLA ideal for standby

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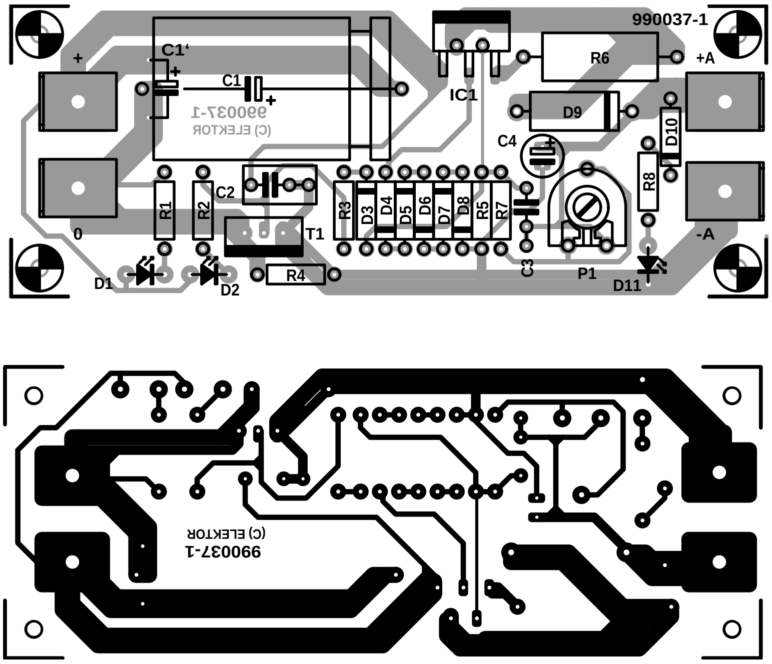
Figure 3. PCB design (board available ready-made).



COMPONENTS LIST

Resistors:
R1,R2,R8 = 10kΩ
R3 = 56kΩ (6kΩ8 for 6V)
R4 = 4Ω7 (see text)
R5 = 4kΩ7
R6 = 0Ω56 5 watt (see text)
R7 = 3kΩ9 (for 12V) or wire link (for 6V)
P1 = 2kΩ preset H

Capacitors:
C1 = 2200µF 25V radial
C2,C3 = 220nF
C4 = 10µF 63V radial

Semiconductors:
D1,D11 = LED, green, low current
D2 = LED, red, low current
D3-D8,D10 = 1N4148
T1 = BD711
IC1 = L200C

Miscellaneous:
PCB, order code 990037-1, see Readers Services page.
Diecast case, size approx. 110 (l) x 60 (w) x 30 (h)
Insulating material for L200C
4 off car-type spade terminal
Mains adaptor socket

Table 1. Max. cell voltage selection

	2.30-2.35V per cell	*2.40-2.45V per cell*
⬆	Longest service life, SLA remains cool during charge; charging allowed at ambient temperature > 30ºC.	Reduced charge time, smaller risk of damage owing to undercharge. Higher and consistent capacity readings.
⬇	Long charge period. Sulfation may occur if no periodic topping charge is applied. Low, inconsistent capacity readings.	Higher battery temperature during charging may reduce battery life. Overcharging may occur owing to cell voltage limit never reached.

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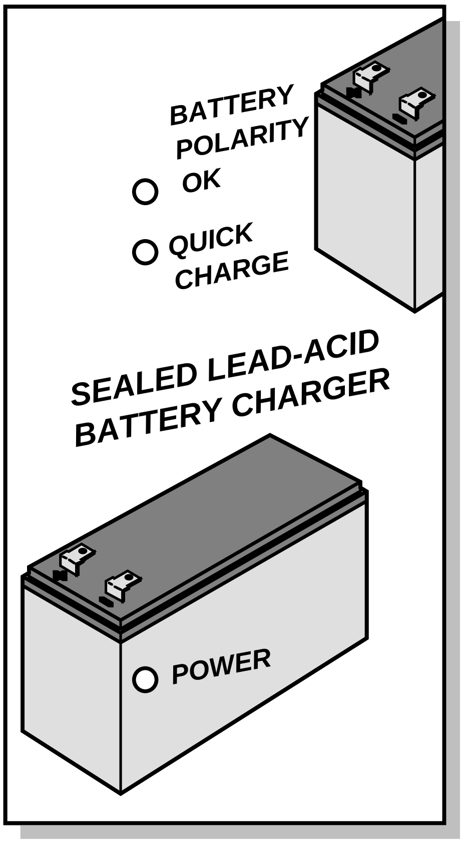
Figure 4. Suggested layout of front panel on diecast case.



use!

Remember that the above is the *algorithm*, i.e., a theoretical construct suggested by the battery industry. In practice, SLA batteries are so resilient and easy-going that a multistage charger with a built-in timer is rarely used.

PRACTICAL CHARGER CIRCUIT

The circuit diagram in **Figure 2** shows an old faithful, the L200 voltage regulator. No boos and catcalls we reckon — this device was chosen because it is cheap, easy to use and widely available. Although the five diodes inserted in its ground line introduce a voltage drop of about 3.5 V, they have in principle nothing to do with the output voltage or current regulation — their purpose is to match the temperature coefficient of the charger (–3.85 mV/ºC) to that of a typical SLA battery. This means that you can safely use the charger at any ambient temperature allowed for the battery (typically –20ºC to +40ºC; check manufacturer's specs). There's another Easter egg: the diodes protect the L200 against reverse-polarized voltages at the output. *Still, don't try this at home.*

Initially, the battery is charged with a current of about 0.2 *C*. This current is determined by the value of R6, see **Table 2**. The resulting voltage drop on R4 is enough to fully open transistor T1. A power transistor is used here because nearly all of the charge current flows through the base-emitter junction (the BD711 is specified at max. 3 A in this respect) LED D2 lights as result of the current flow through T1. The (small) current through R3 causes the output voltage to rise by 0.6 V (12-V configuration) or 0.3 V (6-V configuration).

The actual charge process differs from the theoretical one in a number of respects. Initially, the battery is 'pumped' using a constant current of 0.2-0.5 *C* and the 'low' cell voltage of 2.30 V (i.e., a battery voltage of 13.8 V or 6.9 V). A flat battery will draw enough current (but never more than determined by R6) to make the L200 supply its 'elevated' output voltage of 2.45 V per cell. This will happen so quickly as to create the impression that the charger supplies 2.45 V/cell straight away. Normally, the charging current resulting from (1) the empty battery and (2) the elevated cell voltage will be so high as to cause the L200 to go into current-limiting (using R6) and keep functioning like that for several hours on end. As the battery gradually accepts the charging energy, its cell voltage rises to the charging level of 2.3 V/cell or 2.45 V/cell. The charging current then drops because the battery can not accept more current. However, there is sufficient current flow to keep T1 conductive (via R4) and so maintain the elevated charging voltage.

At a certain point, the charging current will have dropped to a value of about 0.02 *C*. The battery is then considered 'full'. With T1 being turned off by R4, the L200 switches to the lower cell voltage of about 2.3 V/cell which serves as the 'float charge' voltage. The present charger is 'intelligent' in as far as it does not produce the elevated charging voltage any longer than strictly necessary. Also, in standby use, the battery is automatically switched to 'rapid' charging when a large amount of current is consumed by the load.

If no voltage is applied to the charger input, a battery left connected to the output will discharge across the same output. Thanks to diode D9, the discharge current is limited to about 1 mA plus the current through low-current LED D11 (approx. 2.5 mA). No cause for alarm!

SLA batteries being allergic to large ripple voltage levels, the circuit has been extended with a large reservoir capacitor, C1. A much smaller capacitor, C3, has been added to keep the L200 unconditionally stable.

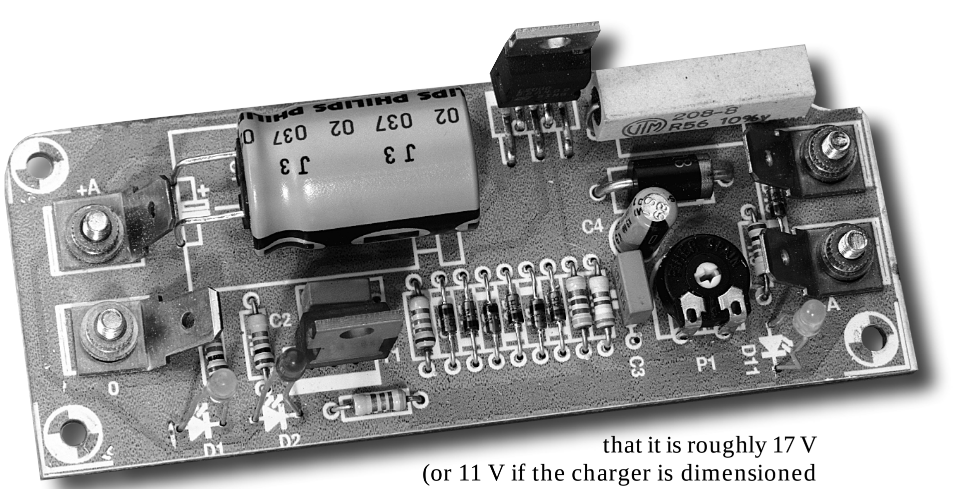
INPUT VOLTAGE TO THE CHARGER

Unless you are using high-capacity SLA batteries ($C > 10$ Ah) a mains adaptor with dc output is recommended as the input voltage source. With safety and cost in mind, this is an obvious

Table 2. Component values

Component	*6-volt SLA battery*	*12-volt SLA battery*	*Notes*
R7	Wire link	3.9 kΩ	
R3	6.8 kΩ	56 kΩ	
R6	0.45 x I [ohms]	0.45 x I [ohms]	Determines maximum charging current only. I = 0.2 C to 0.5 C
R4	0.5/0.02 C [ohms]	0.5/0.02 C [ohms]	Determines threshold for cell voltage reduction to 2.3 V and standby charging current. Select nearest E12 value, target standby current is 0.02 C
C = nominal capacity of battery (Ah specification) I = initial charging current			

Figure 5. Prototype, ready for fitting into the diecast case. The L200 has to be secured to the inside of the case using heatsink insulating materials.



choice. The power rating of the adaptor depends on the capacity of the battery and the patience you can put up for a complete charging cycle. Typically, a mains adaptor set to '12V' will easily supply 17 V to light loads, and that is just about sufficient for the present circuit. Do check however that this voltage does not drop below 17 V when a current of 0.2 *C* is drawn. For example, if you are using a 12-V 4-Ah SLA, the initial charge current is of the order of 0.8 A, so a fairly hefty mains adaptor will be required. By the way, there is no objection against charging with a lower current. Indeed, while the charge process will simply take longer, the benefit is that you may get away with the use of a medium-power (500-mA) mains adaptor!

For all cases where a mains adaptor falls short of output voltage and current, we recommend the use of a regulated power supply set to 18 V or so. Failing this, build a dedicated PSU consisting of a mains transformer with a 15-V secondary rated at 1.4 times the maximum required current, a bridge rectifier and a smoothing capacitor with a capacitance of about 2200 μF per ampère. Observe safety regulations for all wiring and connections at mains voltage!

CONSTRUCTION

The charger is built on the compact PCB shown in **Figure 3**. This board is easily fitted in a small diecast enclosure that also acts as the heatsink for IC1. The L200 must be fitted with an insulating set (mica washer and a plastic mounting bush). A suggested front panel layout is shown in **Figure 4**.

ADJUSTMENT

Do not yet connect a battery to the output. Apply the input voltage and check that it is roughly 17 V (or 11 V if the charger is dimensioned for 6-V batteries). At room temperature (20-25°C), adjust P1 for an output voltage of 13.8 V (12-V charger) or 6.9 V (6-V charger). Use a short piece of wire to temporarily short-circuit the collector-emitter junction of T1. The output voltage should rise to 14.4 V (12-V charger) or 7.2 V (6-V charger). A tolerance of ±0.1 V is acceptable here. If the voltage is much too high, increase the value of R3. The converse applies if the voltage is much too low.

PRACTICAL USE

Make a habit of following this order:

- Observe the battery polarity
- Connect the battery to the charger
- Check that D11 lights
- Apply the input voltage to the charger

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